ESD Repair of Army Main Battle Tank Components

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Outline

- **ESD applications (ARL and ANAD)**
  - **ESD accomplishments**
  - **Repair of M1A1 tank cannon cradle**
    - **Optimization of process**
    - **Preparation of DEM/VAL**
    - **Successful field repairs**
  - **Repair of M1A1 tank sun gear shaft**
    - **Process parameters optimized**
    - **Preparation of DEM/VAL**
    - **Formation of “Halo Effect”; inconsistent results and problems due to chrome plating. Effort focused on damage through chrome plating into AISI 9310 base metal.**

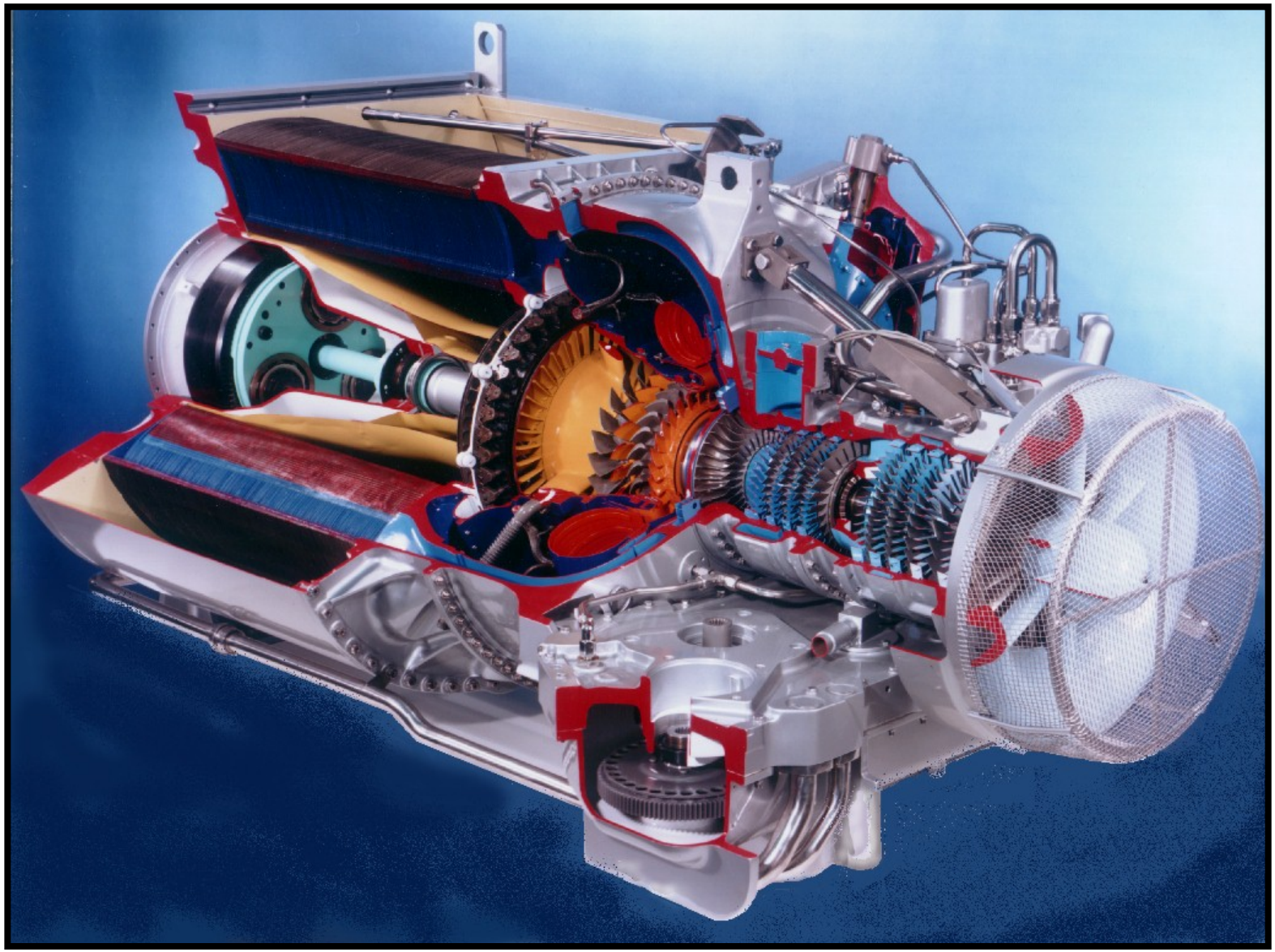
Army ESD Accomplishments

- **Training completed at Anniston Army Depot (ANAD).**
- **Training held at ARL with Boeing, Sikorsky, ANAD and ARL in attendance.**
- **Component-specific training held at ARL by Advanced Surfaces and Processes, Inc. (ASAP) with ANAD in attendance.**
- **ARL and ANAD have completed procedure and repair of M1A1 Cannon Cradle and M1A1 helical gearshaft (“Sun Gear”)**

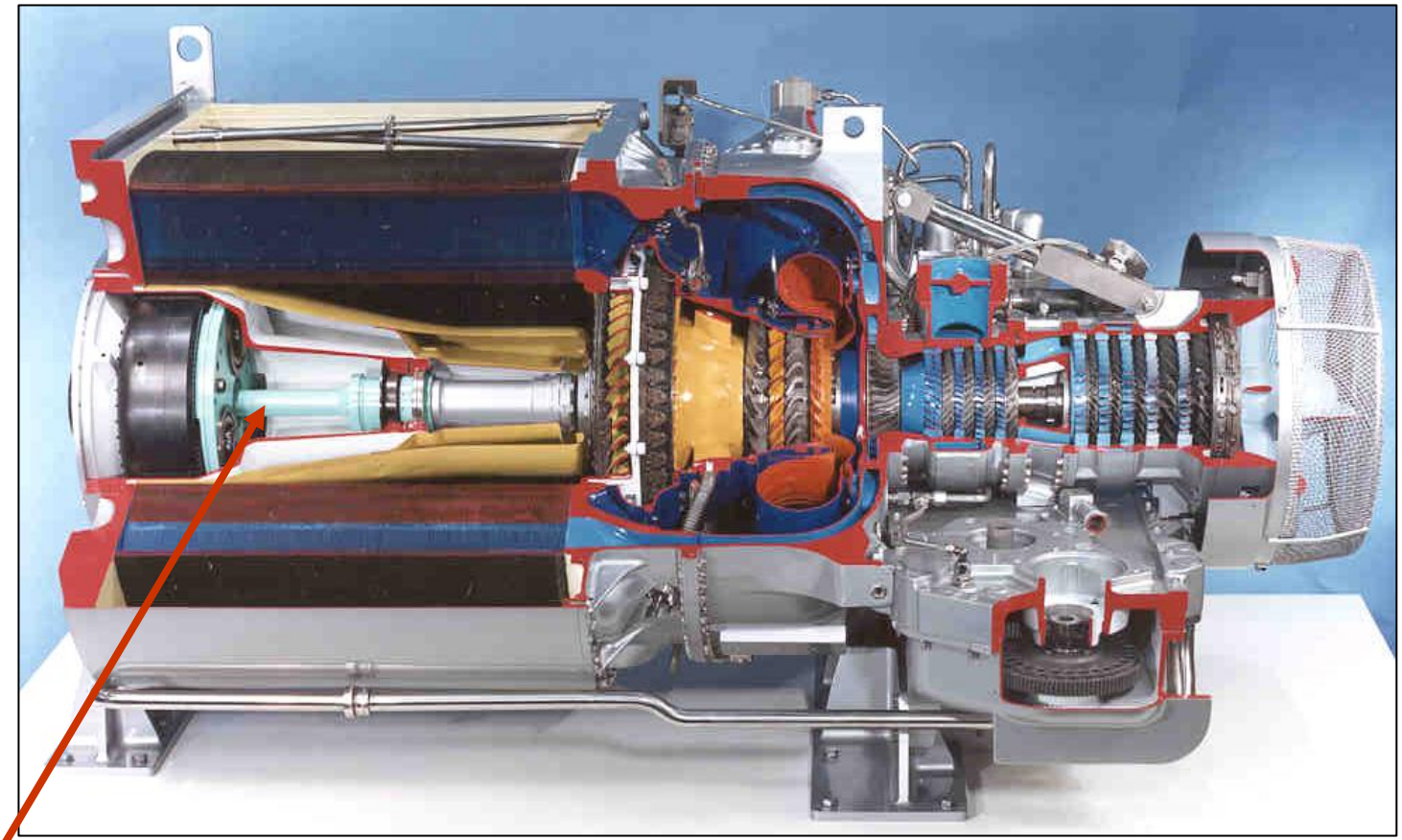
Repair of M1 Sun Gear Shaft

- Small corrosion pits and wear marks noted on chrome plated surfaces on the exterior and interior of the Sun Gear Shaft. Some damage extends into base metal
- Shaft is AISI 9310 steel with chrome plating in some regions.
- Shaft is part of the RGB (Reduction Gear Box), which transmits power from the M1's turbine engine to the transmission.
- The Sun Gear Shaft has an input RPM of 32,000, and drives a planetary gear with an output of 3,000 RPM.
- The seals which ride on the chrome plated surfaces are carbon based spring loaded seals, providing very low levels of wear to this part.

M1 Turbine Engine and Reduction Gear Box

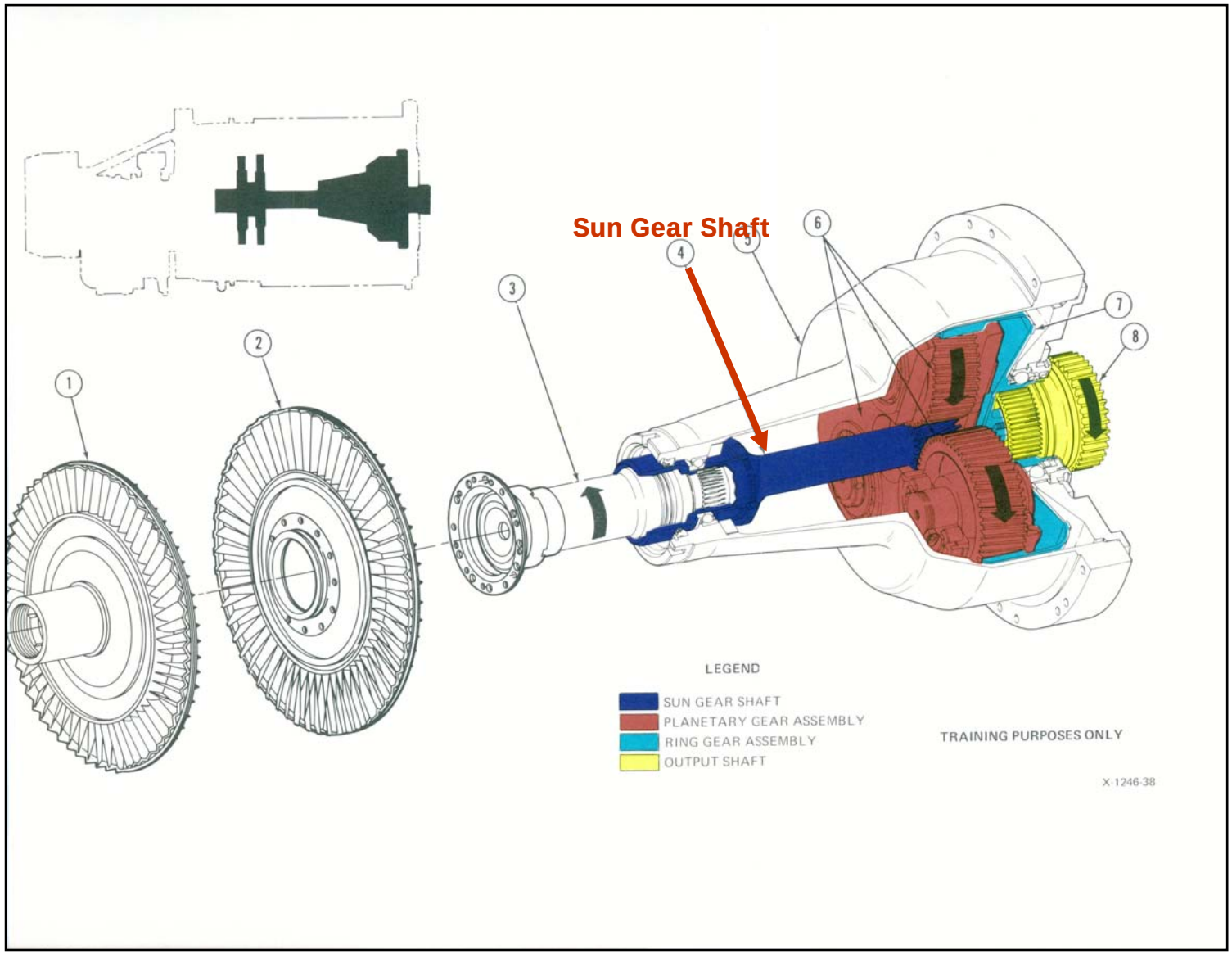


Placement of Sun Gear Shaft in M1 Engine and RGB

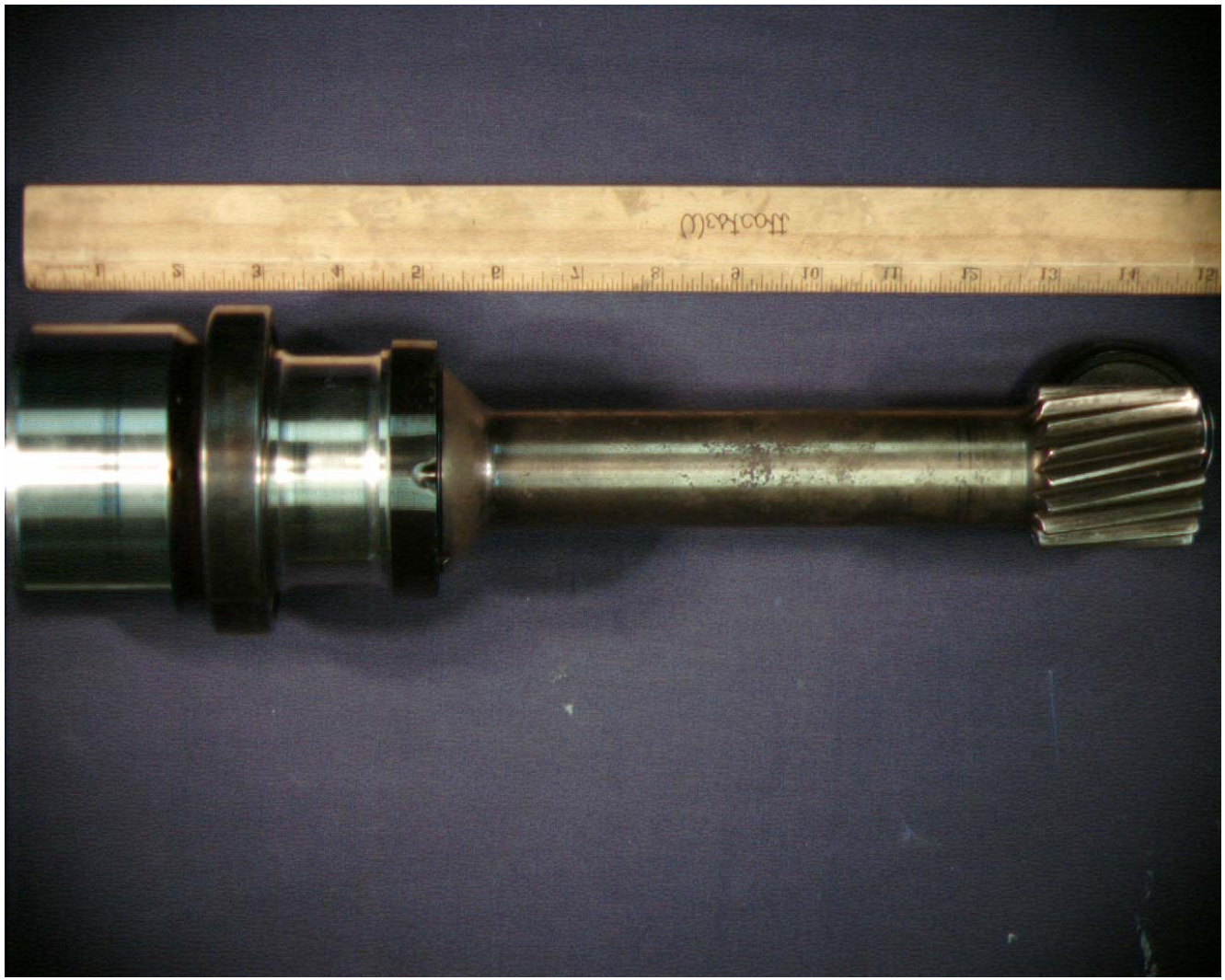


Sun Gear Shaft

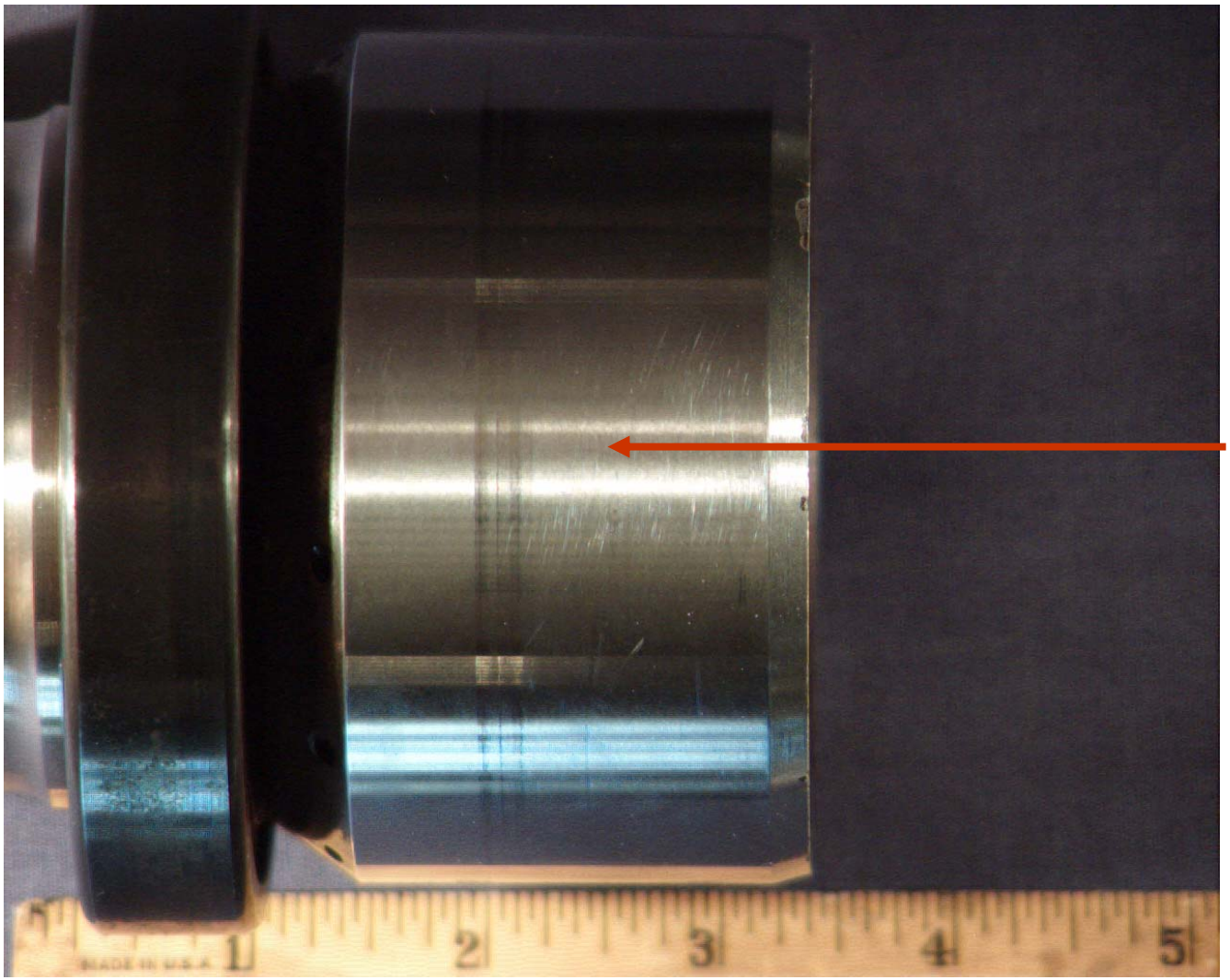
Cut-Away of M1 Reduction Gear Box



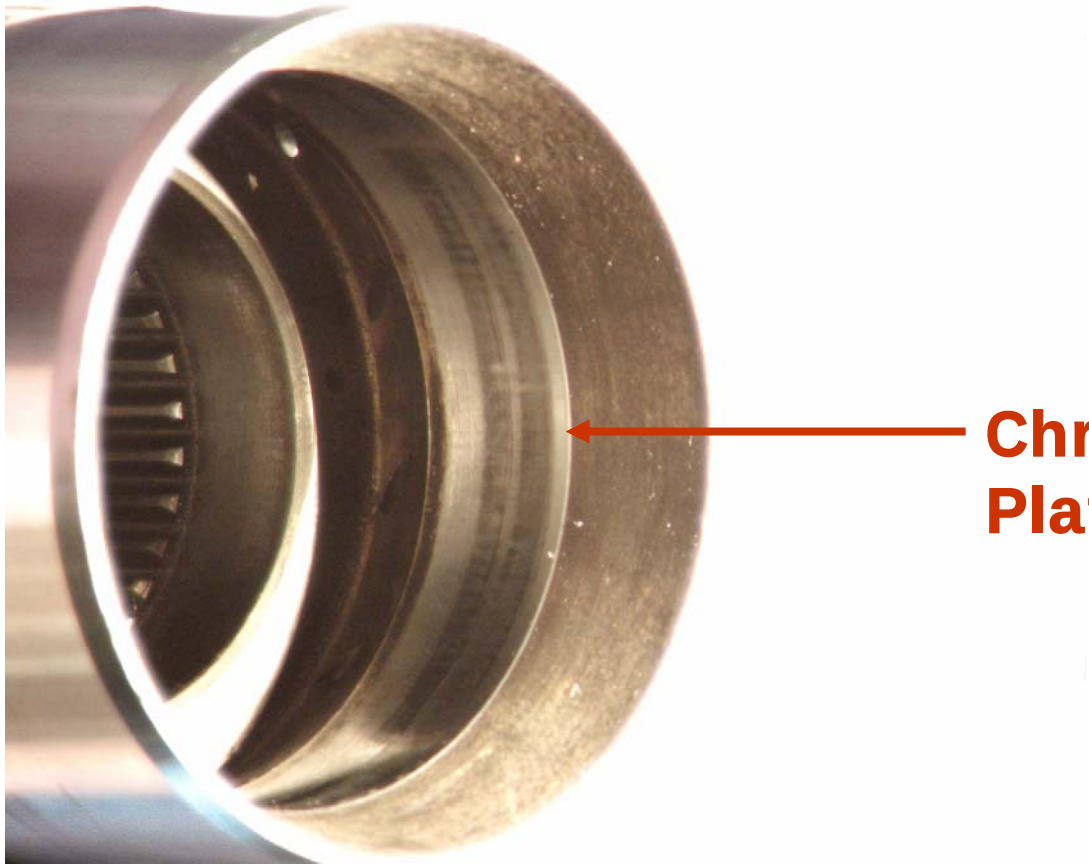
Photograph of M1 Sun Gear Shaft



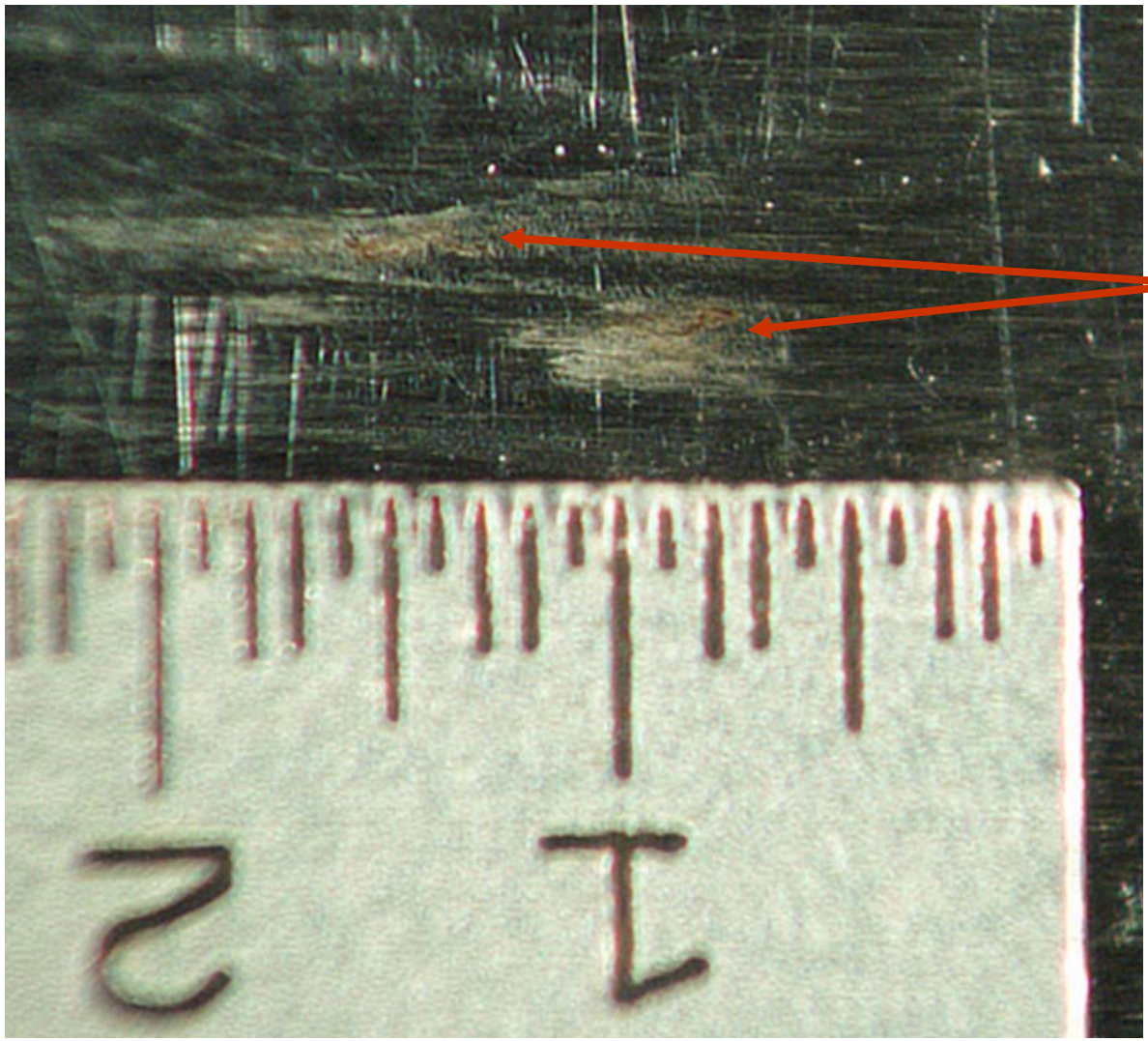
Exterior Chrome Plating on M1 Sun Gear Shaft



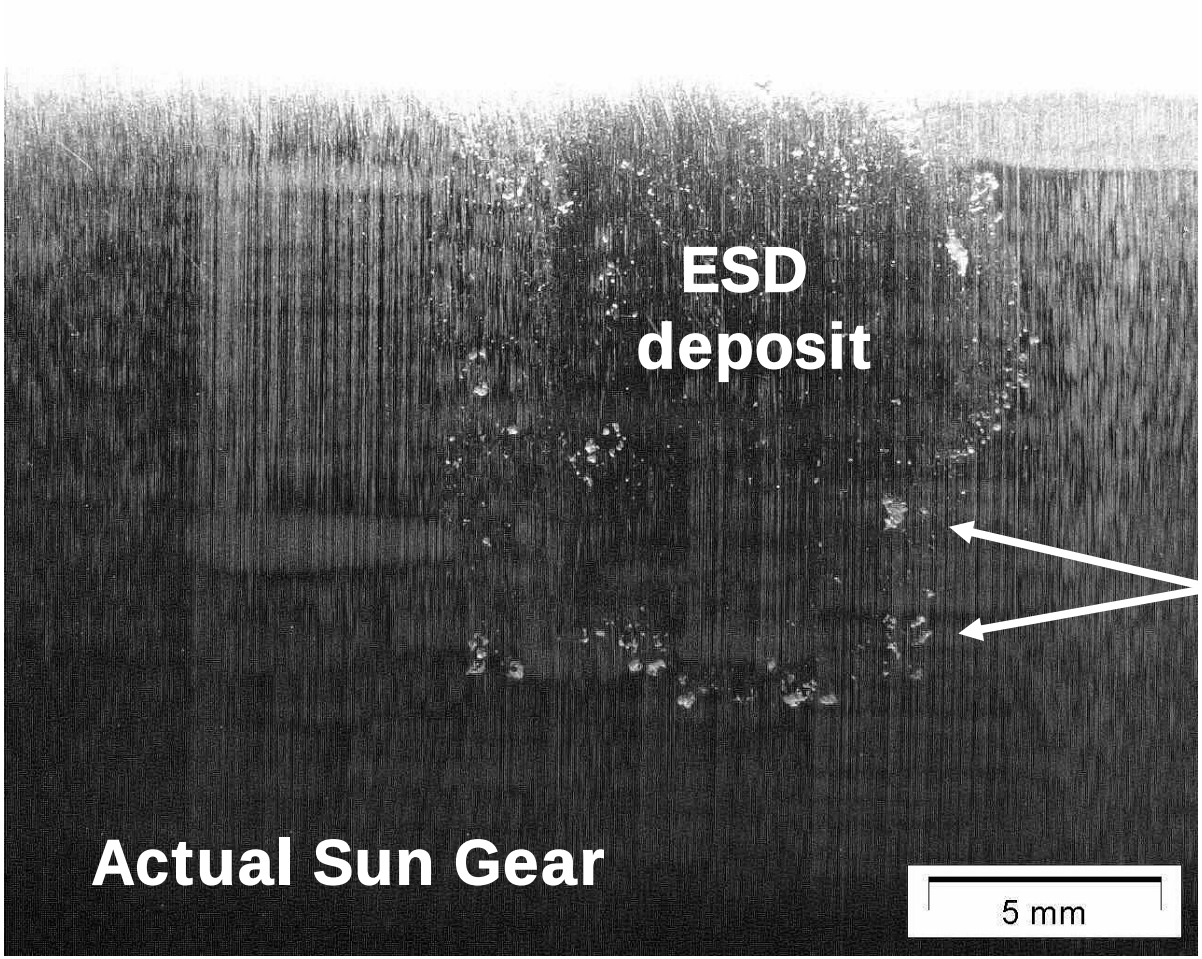
Interior Chrome Plating on M1 Sun Gear Shaft



Corrosion Pits on M1 Sun Gear Shaft Chrome Plating



Defects Noted at Interface of Chrome and ESD

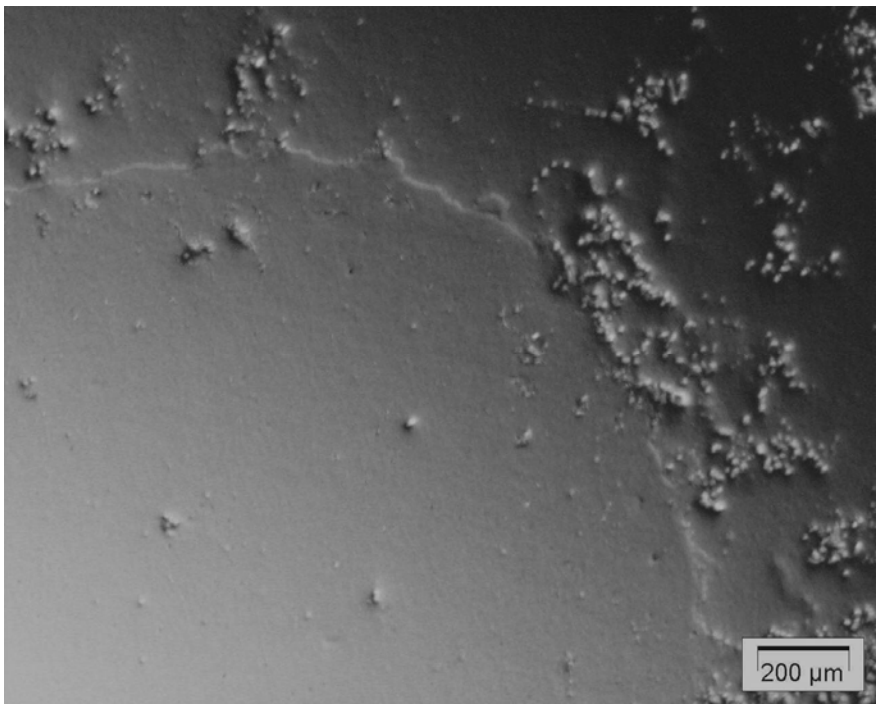


"Halo" effect around periphery of ESD deposit on chrome-plated sun gear.

Pitting at periphery of deposit

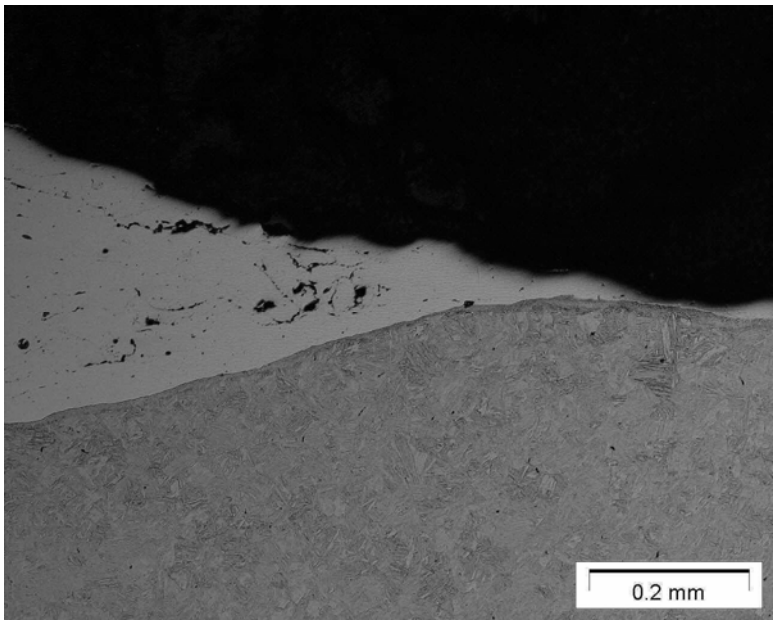
Inconsistent Results with ESD and Chrome Plating

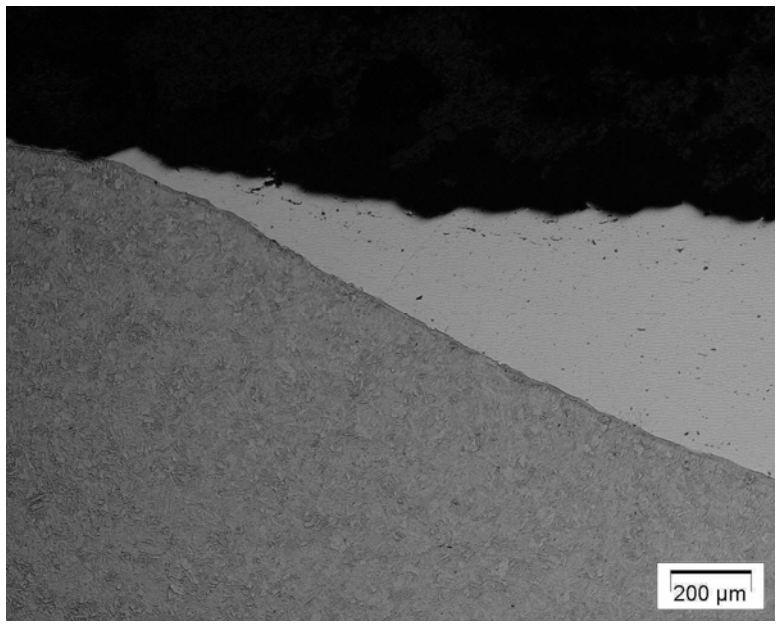
- Repair of defects within chrome plating led to inconsistent ESD results. A defect characterized as the “Halo Effect” was noted in many cases. This defect occurs at the interface of the deposit and the chrome plated substrate. **This problem convinced ARL and ANAD to only repair pits and wear marks through the chrome plating into the base metal**.



“Halo” effect around periphery of ESD deposit on chrome-plated sun gear.

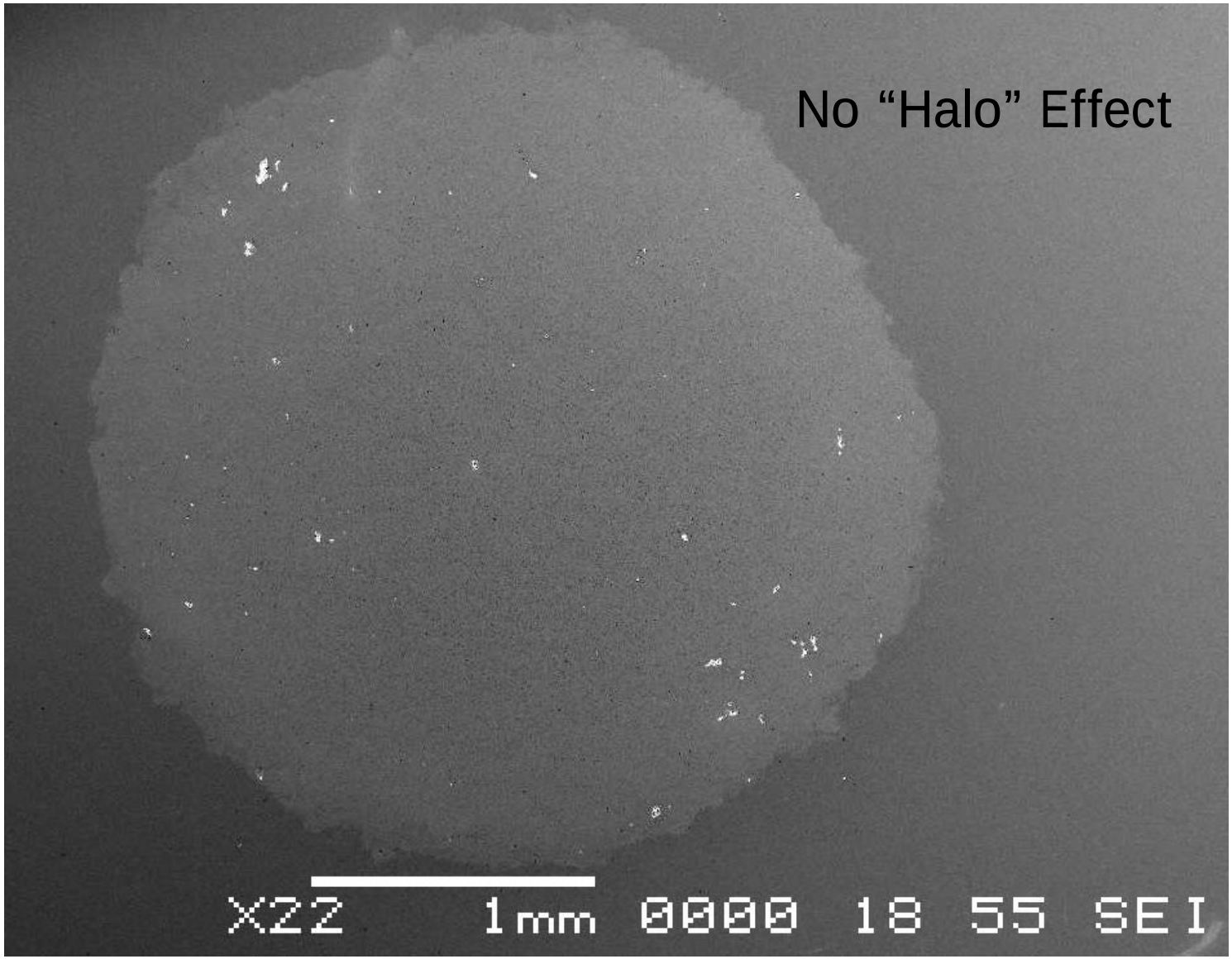
Defects Noted at Interface of Chrome and ESD Repair



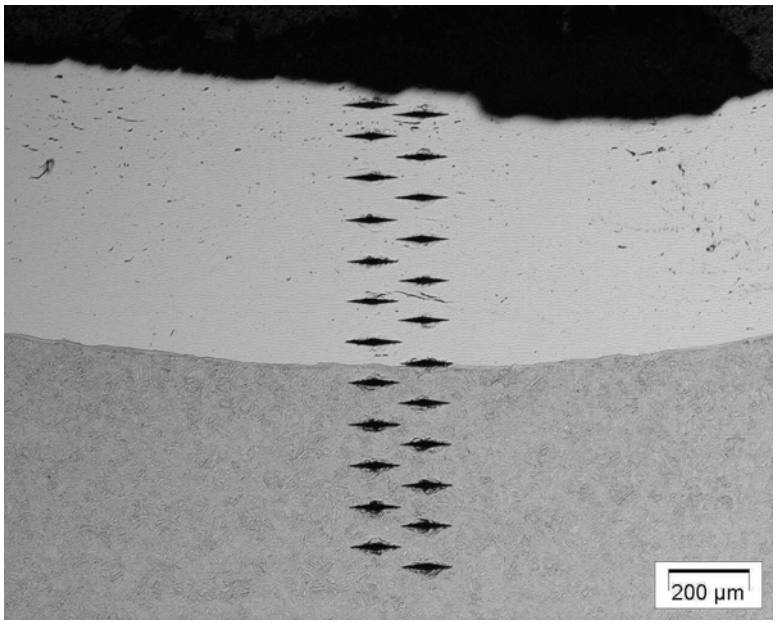


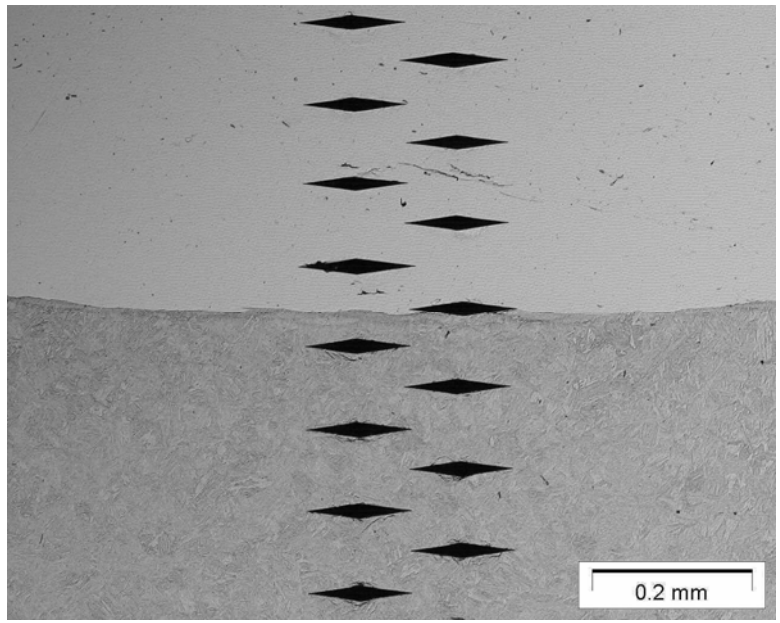
- ESD of defects in chrome-plated steel yielded mixed results – porosity noted (left), defect-free repair (right).

SEM Micrograph of ESD Repaired Type 1b Defect after Chrome Removal



Microhardness Through an ESD Deposit

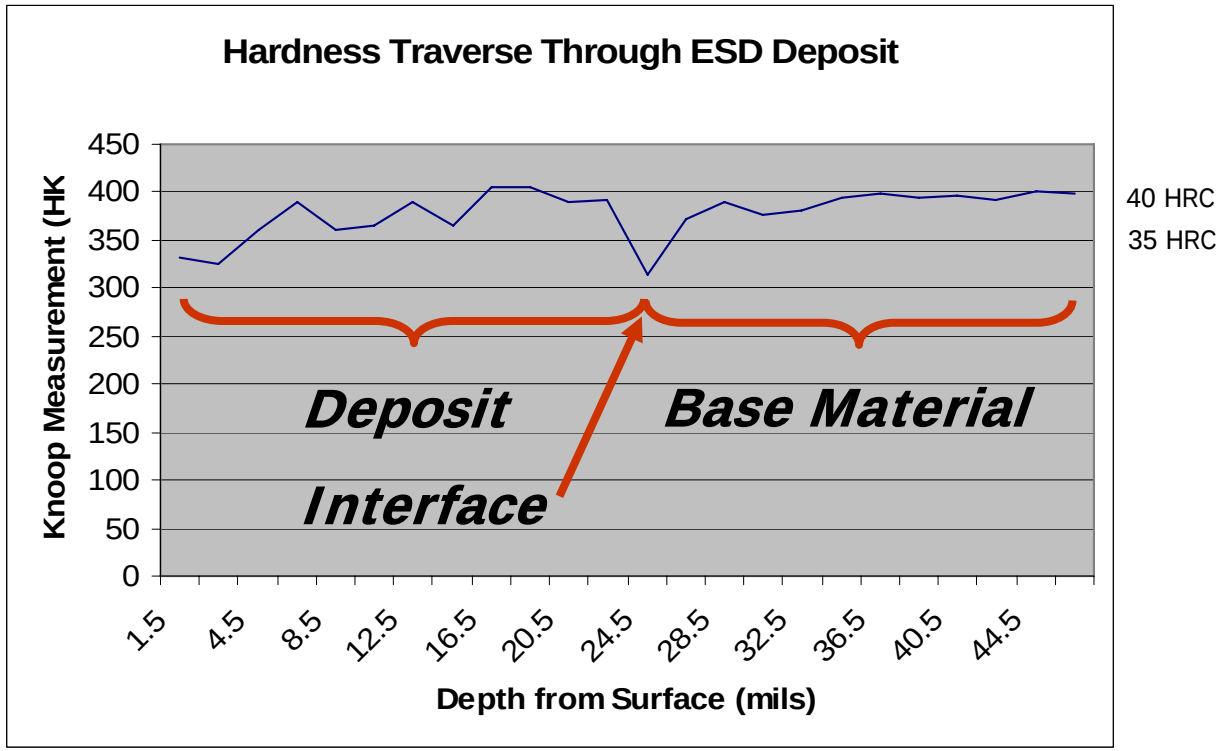




- Knoop microhardness measurements taken through ESD deposit into base material (AISI 9310). Photo on left is 50x magnification, photo on right is 100x magnification. No appreciable hardness difference between deposit and base material.

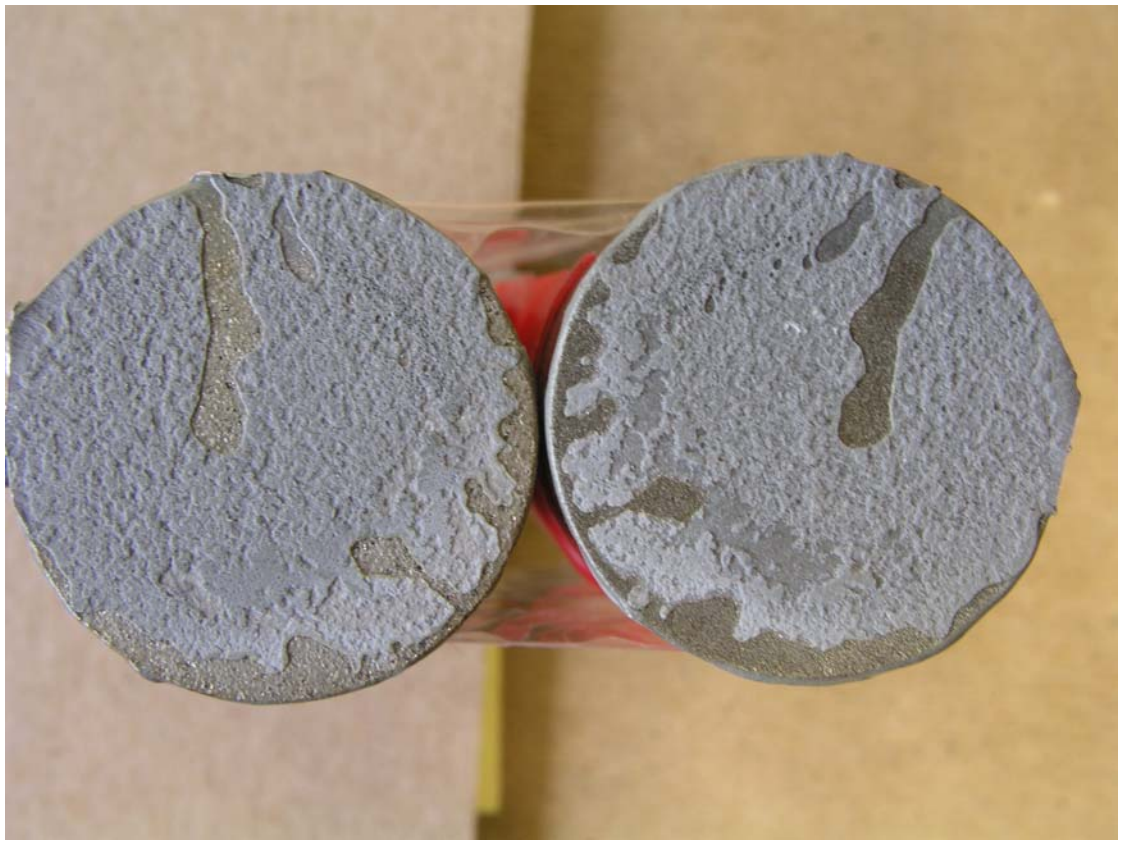
Microhardness Through an ESD Deposit

- Knoop microhardness measurements (500gmf load, 50x objective) were taken through ESD deposits into base material (AISI 9310). Typical hardness results are as shown:



Tensile Test Bond Bars

(ESD on 9310 Steel)



Bond Bar Tensile Test Results

Bond Bar	Tensile Strength (psi)
1	10,453
2	9559
3	7891
4	10,136
5	10,960

Note: All were adhesive bond failures

ESD Repair Procedure for M1 Sun Gear Shaft – DEM/VAL

- Remove Chrome Plating via grinding.
- Using a hand held grinding tool with mild abrasive bit, grind away any corrosion product until clean metal surfaces are present.
- Clean the surface to be repaired with a solvent such as ethyl alcohol and dry.
- Apply a 35 CFH flow of argon gas over the area to be repaired.
- Install a clean Inconel 718 electrode in the rotating torch.
- Perform ESD process to fill the corrosion pit to a level above the surface of the part.
- Using a hand held grinding tool and a polishing bit, polish away excess ESD material until the surface being repaired is flat and flush with the rest of the part.
- Finish polishing the surface of the part using an ultra-fine grit silicon carbide paper (>1200 grit).
- Plate with Chrome to thickness of 0.002-0.005.”

Comparison Between M1A1 Tank Cradle and Sun Gear DEM/VALs

- Cradle:
  - Material AISI 4130 chrome-plated steel
  - Electrode: Inconel 718
  - ESD Unit settings:
    - Rotating Torch
    - Pulse Rate = 580 Hz
    - Capacitance = 20 µF
    - Voltage = 100 V

- Sun Gear:
  - Material AISI 9310 chrome-plated steel
  - Electrode: Inconel 718
  - ESD Unit settings:
    - Rotating Torch
    - Pulse Rate = 400 Hz
    - Capacitance = 30 µF
    - Voltage = 140 V

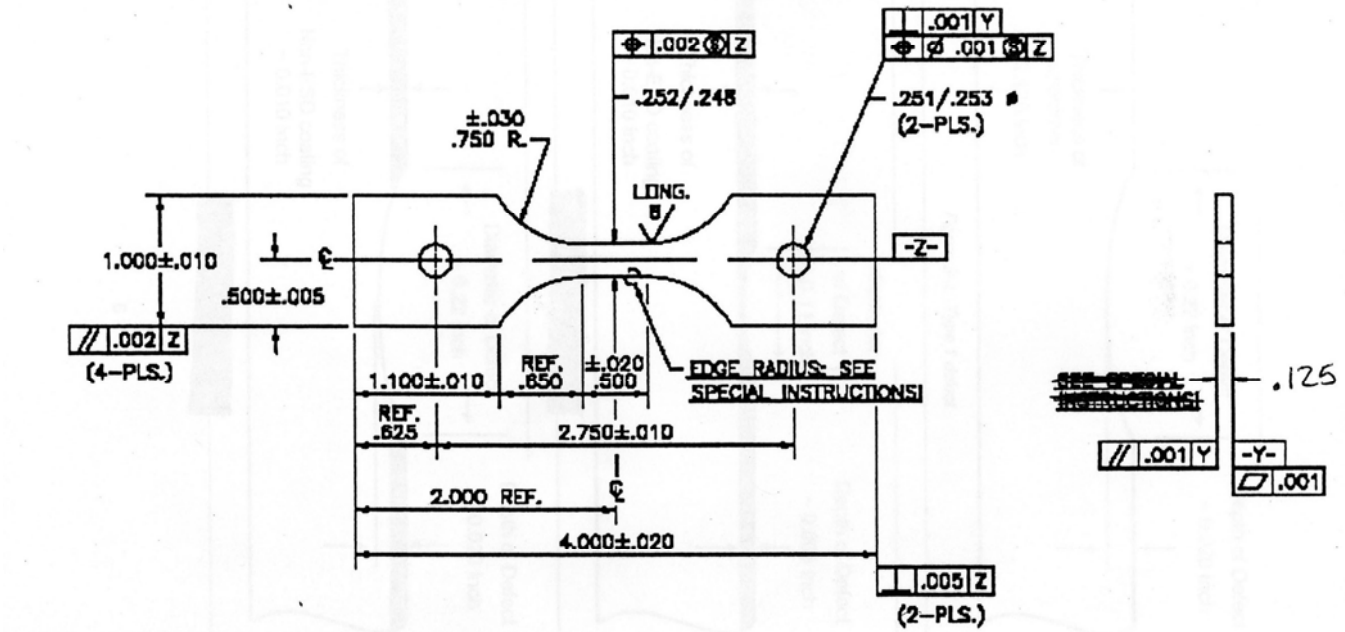
Benefits of ESD Repair of M1 Sun Gear Shaft

- ANAD reported 100 of these sun gear shafts per month which are inoperable as a result of corrosion pitting.
- Each of these parts costs $2195.00 to produce.
- The estimated cost for ESD repair of the sun gear shaft is $489.00, which is broken down to:
  - 6 Man-hours of labor per part @ $76.50 /hr = $459 per part
  - $30 per part in consumables and equipment depreciation.
- Estimated savings for reclamation of M1 sun gear shaft is $1706.00 per part.
- Total estimated savings for reclamation of M1 sun gear shaft is $2,047,200.00 per year.

TACOM Qualification for ESD Repair of M1 Sun Gear Shaft

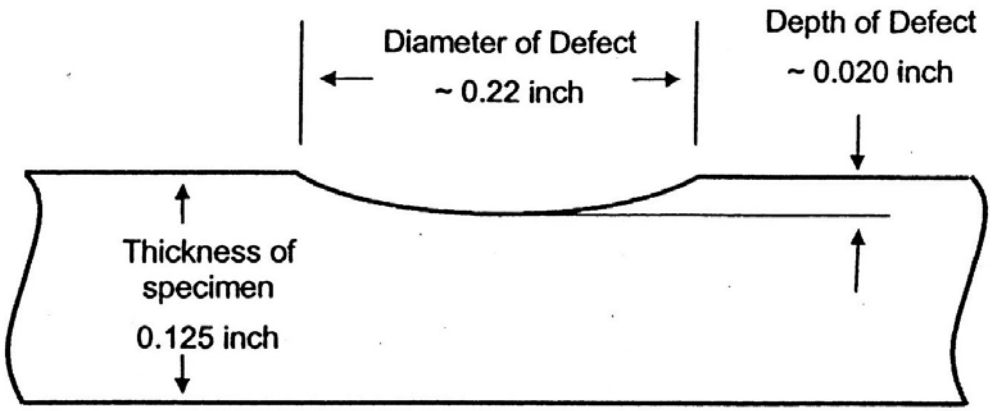
- The ESD Repair Procedure has been forwarded by ARL to ANAD for TACOM Approval and Qualification Testing
- The following tests will be conducted to validate the ESD repair:
  - Fatigue testing at ARL
  - AGT 1500 (Advanced Gas Turbine) engine test stand (25 and 100 hr intervals)

Fatigue Testing Specimen



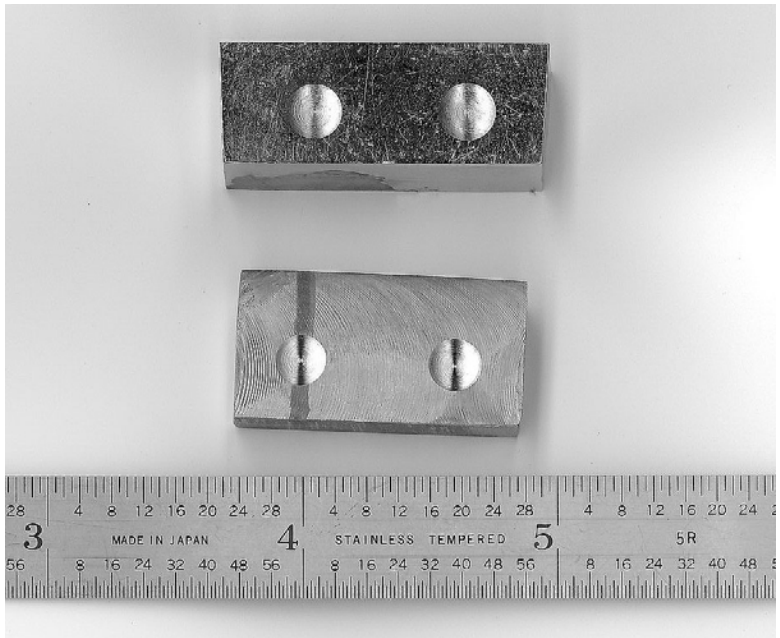
DRAWING NOT TO SCALE!
MINIMUM GAGE WIDTH MUST BE IN THE CENTER OF THE GAGE LENGTH!
REMOVE ALL BURRS AND SHARP EDGES WITH .010/.020 RADIUS OR CHAMFER

Fatigue Specimen Defect



Type 1 Defect to be machined into center of gage section of fatigue specimens and ESD filled.

Fatigue Specimen Defect



Type 1 Defects machined into chrome plated (top) and bare AISI 9310 steel samples. These defects were ESD filled as practice for fatigue test specimen deposition.

AGT Testing

Mechanic operating an AGT-1500 Engine Test Stand. A similar test stand will be used for future testing of sun gears with ESD deposits.